



Wind Generation Forecasting: Status and Prospects for Improving System Integration

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Wind Generation Impacts

- ◆ Wind is an energy source
- ◆ Power system is operated in a capacity framework
- ◆ Issues
 - Increase in net load variability (minutes, hours, days)
 - Increase in net load uncertainty (day ahead, hour or hours ahead)
 - Increase in energy uncertainty over a period
- ◆ System concerns
 - Cost
 - Reliability

What is “Integration Cost”?

- ◆ From cost-based perspective
 - Increased cost of serving load not served by wind
 - Determined by comparing wind to equivalent energy source that imposes no incremental burden on operations
- ◆ Elements
 - Conventional ancillary services – regulation, etc.
 - Increased costs due to variability of wind generation
 - Increased costs due to increased uncertainty in unit commitment

UWIG Survey of Integration Studies – ca. 2003

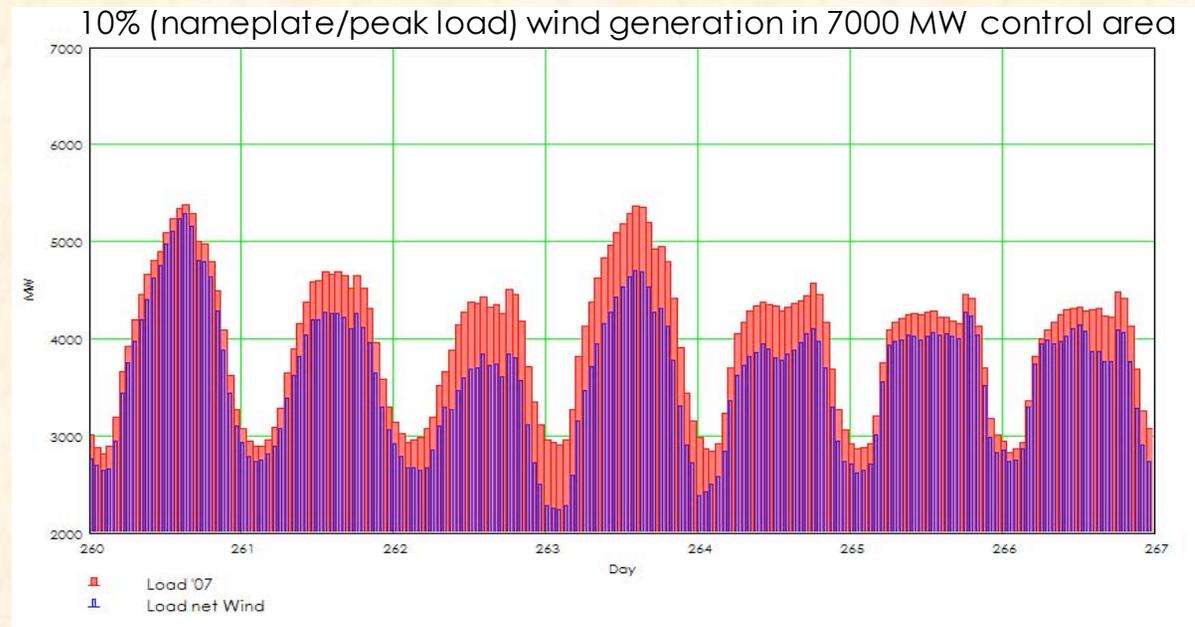
- ◆ Different assumptions, methods, and system characteristics complicates direct comparisons of results
- ◆ General view is that integration costs are modest for lower penetrations of wind generation (up to 15 or 20%)

Study	Relative Wind Penetration (%)	\$/MWh			
		Regulation	Load Following	Unit Commitment	Total
UWIG/Xcel	3.5	0	0.41	1.44	1.85
PacifiCorp	20	0	2.50	3.00	5.50
BPA	7	0.19	0.28	1.00 - 1.80	1.47 - 2.27
Hirst	0.06 - 0.12	0.05 - 0.30	0.70 - 2.80	na	na
We Energies I	4	1.12	0.09	0.69	1.90
We Energies II	29	1.02	0.15	1.75	2.92
Great River I	4.3				3.19
Great River II	16.6				4.53
CA RPS Phase I	4	0.17	na	na	na

Smith, J.C., et. al. "Wind Power Impacts on Electric Power System Operating Costs: Summary and Perspective on Work to Date" presented at the AWEA Global Wind Power Conference, March 28-31, Chicago, Illinois

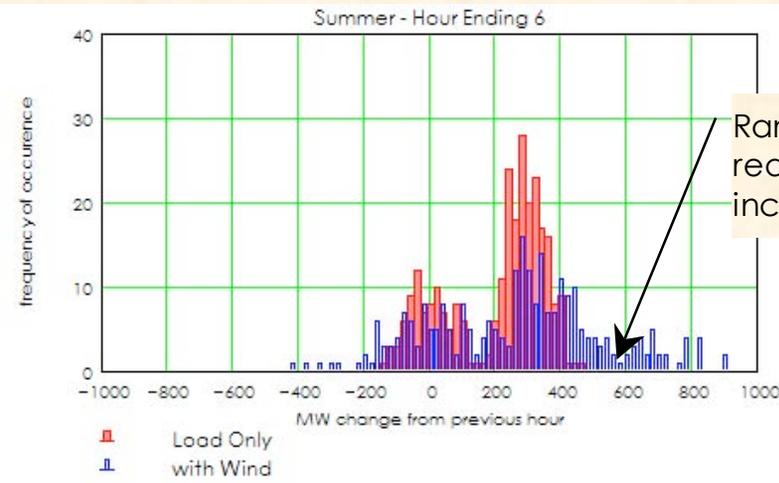
Operating the Power System with Significant Wind Generation

- ◆ Large amounts of wind can substantially alter the familiar “patterns” to which we are accustomed
- ◆ Effective wind penetration can be very high certain periods of the year

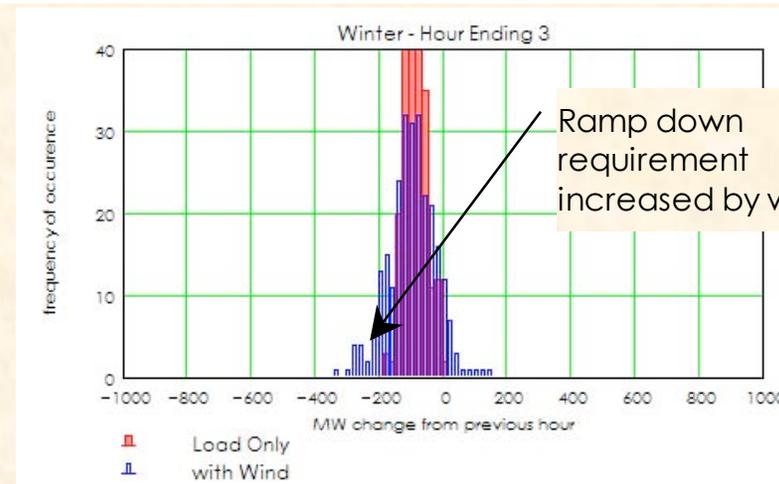


Variability of Control Area Demand

- ◆ Wind generation variability (hour to hour) may also be significant compared to load changes
- ◆ Generation must be made available to meet both planned and actual changes in control area load



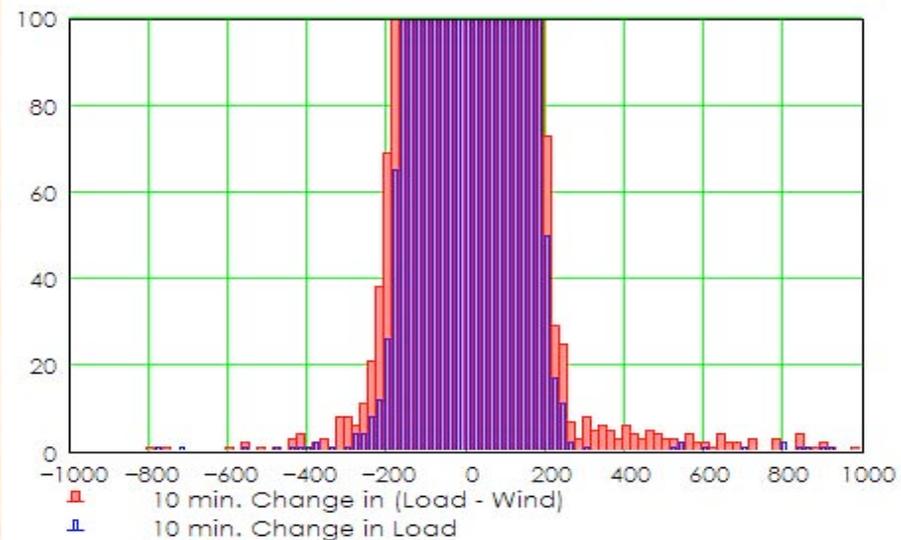
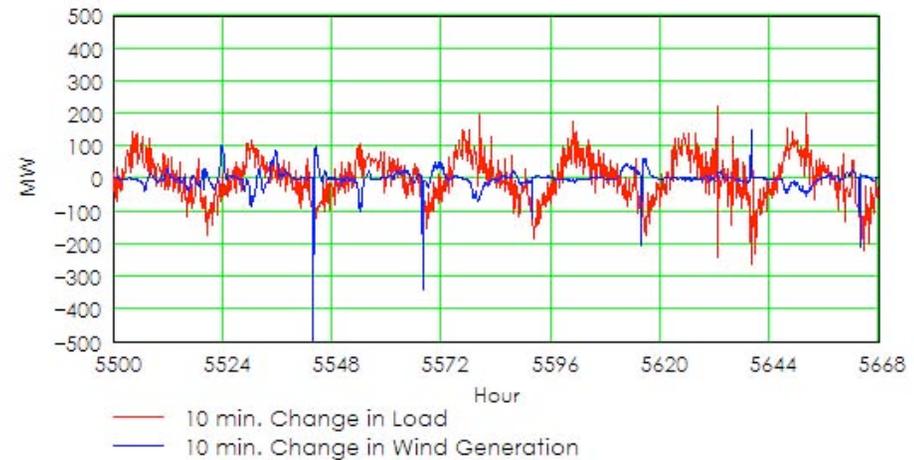
Ramp up requirement increased by wind



Ramp down requirement increased by wind

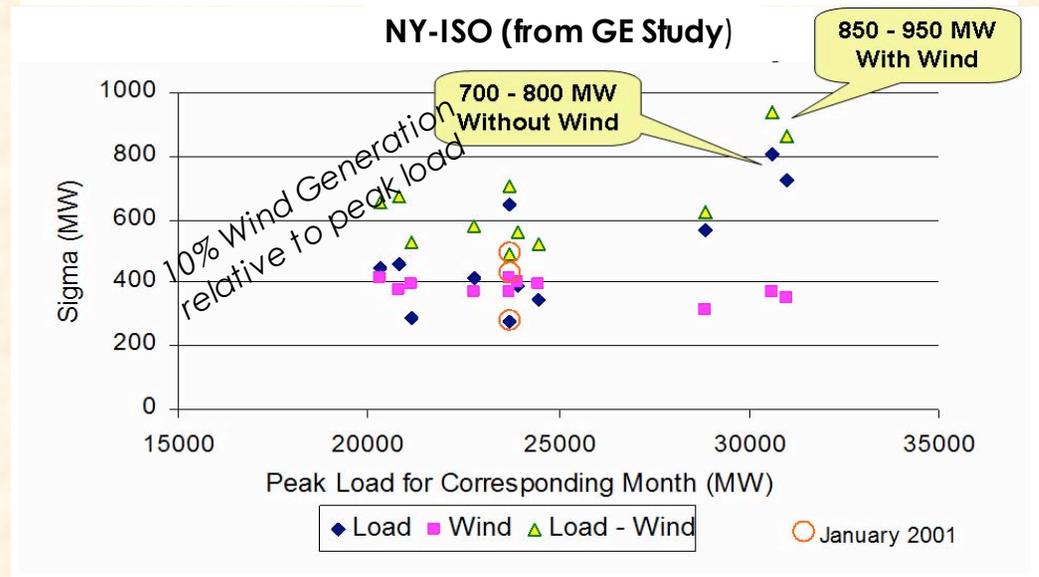
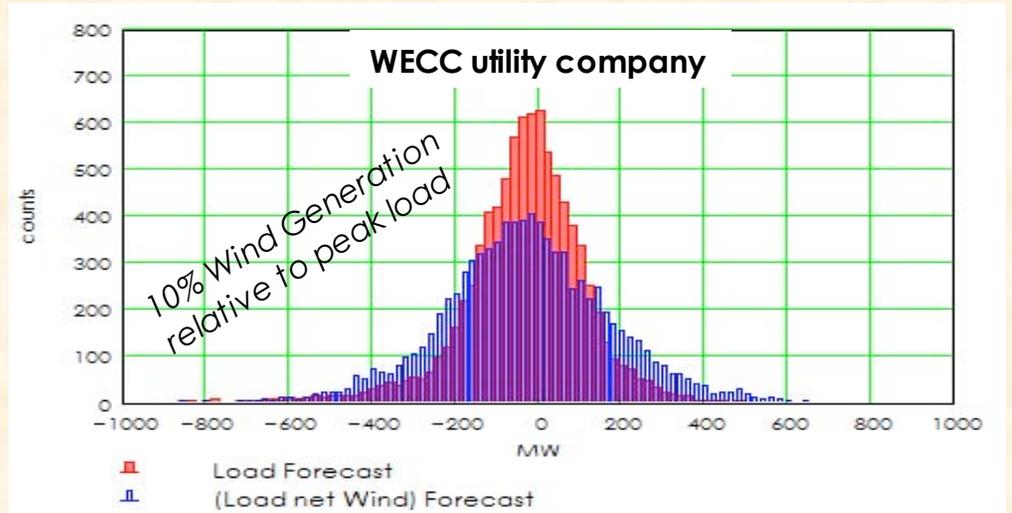
Impacts within the Hour

- ◆ Question: Does wind make control area demand more variable within the hour?
 - beyond regulation time from
 - “granularity” finer than hourly
- ◆ Question: If so, what are the economic or technical consequences?
- ◆ Thoughts to date
 - Diversity reduces demands for regulation, intra-hourly balancing
 - Impacts appear to be very modest for systems studied to date



Next-Day Uncertainty with Wind Generation

- ◆ Current forecasting technology can provide 15% MAE for next-day planning (18 – 42 hours ahead)
- ◆ Hourly errors can be significant
 - Missed timing of frontal passages
 - Hard-to-forecast patterns
- ◆ Relative to Load Forecast uncertainty
 - Wind generation may be same order of magnitude, but weakly correlated
 - Net effect on uncertainty is diminished



Market Impacts

- ◆ Wind generation forecasting shown to be beneficial for power markets
- ◆ Without forecasting, market players act on bad information

Unit Commitment

\$ 95M

Forecasting Value

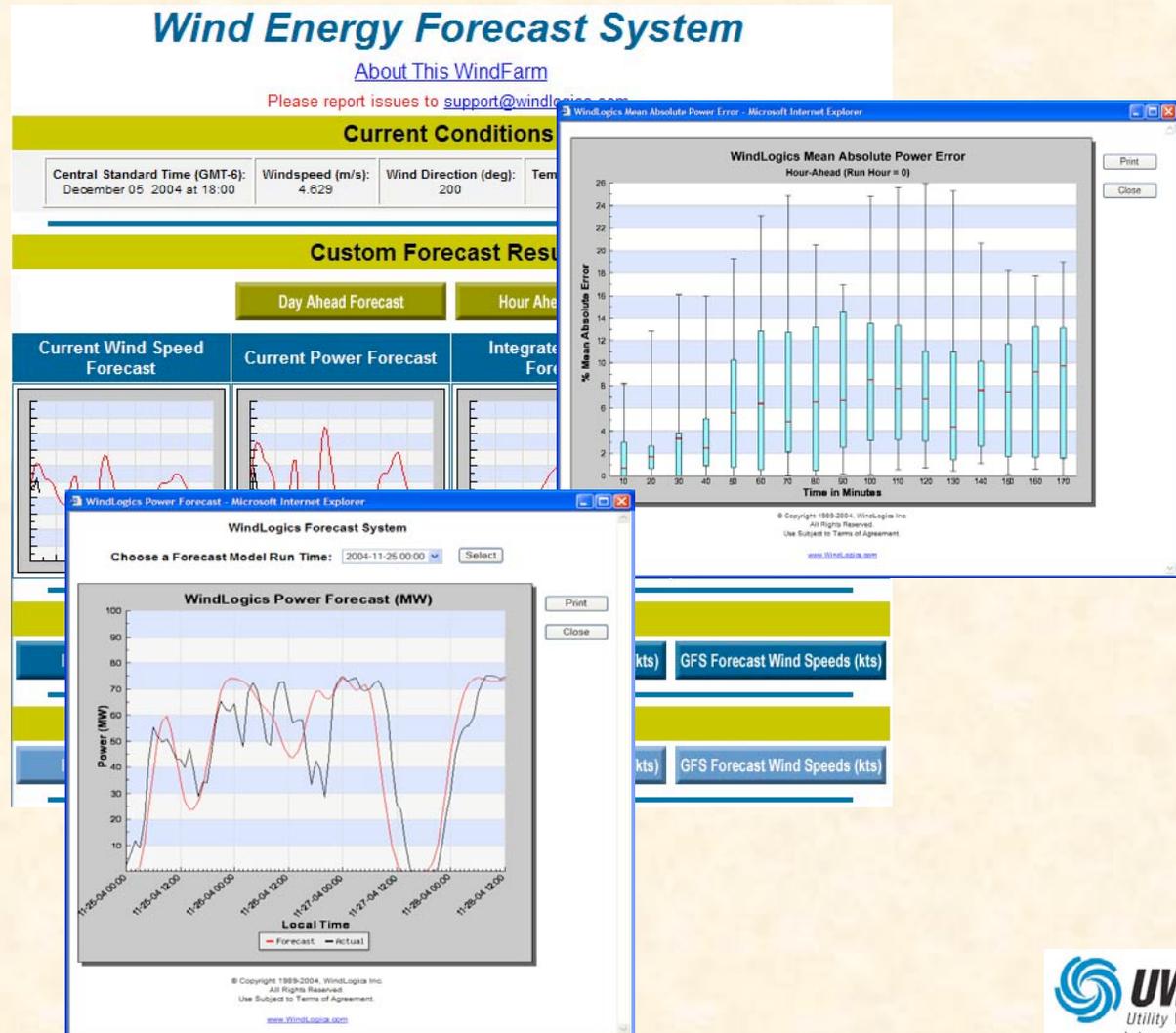
- ◆ Benefits for System Integration
 - Ancillary service cost impact for wind integration
 - Transmission congestion and scheduling
 - Forecast uncertainty is major cost component (irrespective of wind variability)
 - Forecast value grows with increasing wind on grid
- ◆ Benefits to wind plant operators
 - Depends on agreements, penalties, etc.
- ◆ Merchant power strategies & trading
- ◆ Regional differences in power and transmission systems make things interesting...
- ◆ Status:
 - Developing stages
 - Many questions about how/who/where

Insights & Perspectives: Forecasting

- ◆ Recognized as critical, but many questions remain
 - Individual plant vs. centralized forecast?
 - Use of forecast information: as delivered, or should some “hedge” factor be applied when scheduling resources?
 - How can short-term wind generation forecasts (hour or hours ahead) be used to assist with integration of large amounts of wind generation?
 - How might next-day wind generation energy production forecasts be used?
 - Would new algorithms or solution approaches for the unit commitment problem with substantial wind generation produce better results?

State of the (commercial) Art in Wind Generation Forecasting

- ◆ Many systems have demonstrated value
- ◆ Grid-side applications and expectations not established



Focus on Wind Generation Forecasting: Xcel Energy RDF Project

- ◆ Project Elements
 - “User” requirements for BA-wide wind generation forecasting system
 - Forecast “products”
 - » Day ahead forecasting for power trading
 - » Short-term forecasting for operations cost reduction, reliability enhancement
 - » “Warning” system for unusual events
 - R&D on operating strategies, utilization of wind generation forecast data, value
 - Improved algorithms for unit commitment, short-term scheduling, reliability assessment
- ◆ First project to formally address some important current questions
 - Benefits of “central” vs. “individual” wind plant forecasts
 - Value of real-time meteorological modeling, enhanced observational data

Summary: Wind Integration Costs from North American Studies

- ◆ A number of studies conducted over past five years
- ◆ More in progress
- ◆ Findings
 - Total integration costs for modest penetrations of wind generation (to 15 or 20%) range from a couple to \$5/MWH of delivered wind energy
 - Costs due to planning uncertainty and multi-hour variability seem to be most significant
 - Regulation costs are small
- ◆ Much work remains
 - Forecasting impact/value
 - Sensitivity of integration costs to resource portfolio, operating practices
 - Market impacts/structure
 - Enhanced algorithms for planning with higher uncertainty
 - Use of short-term forecast information in RT operations

Ongoing Wind Integration Studies and Assessments

- ◆ Assessment of **Integration** questions also continues in the form of specific, focused studies, e.g.:
 - Xcel Energy – Minnesota (integration cost study)
 - Xcel Energy - Colorado (integration cost study)
 - State of Minnesota (Dept. of Commerce)/Xcel RDF
 - Sacramento Municipal Utility District (prospective integration study)
 - HELCO and MECO (Hawaii)
 - Public Service New Mexico
 - BPA
 - Manitoba Hydro (integration study)
 - AESO (wind generation market impact assessment)
- ◆ Wind generation forecasting is an important element of each
- ◆ Much activity underway; difficult to track

UWIG Role in Wind Integration

- ◆ Wind generation moving forward quickly
 - Power industry forums (e.g. IEEE PES) playing catchup
 - UWIG working to bridge gap
- ◆ UWIG providing a forum for keeping abreast of developments
 - Presentation and discussion of results, methods, data
 - Focused activities in user groups
 - Special topic workshops (e.g. forecasting, transmission issues, control area operating issues, interconnection)
- ◆ Technical review for collaborative projects
 - Xcel-MN DOC
 - Xcel-PSCo.
 - Xcel RDF
 - SMUD
- ◆ Next meeting in Sacramento (Fall, 2005)